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(54) NON-RETURN VALVES

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German company, of Berlin and Munich, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a non-return valve for, for example, use with a pump for conveying gaseous and/or liquid helium.

Known valves for such a use are generally opened by the pressure of a gas or liquid acting on the outer surface of a valve closure member. As soon as this pressure eases or ceases completely, the valve closes as a result of a corresponding counterpressure which is generated on the valve closure member by a valve spring, by the medium pumped in the opposite direction, or by the valve closure member itself as a result of its own weight.

In pumps for conveying liquid helium a lowering of the boiling point should be avoided to prevent the helium evaporating. This lowering of the boiling point is the result of a formation of underpressure which occurs in a suction process. Since liquid helium evaporates very easily where an underpressure exists a suction process must be avoided at the inlet valve of a helium pump. The helium reaching the inlet valve should therefore open the valves only as a result of a pressure acting from the exterior and then be able to flow into the pump chamber of the connected pump.

Further no substantial increase in the flow resistance should occur at the inlet valves of such a pump; otherwise a certain amount of underpressure would be created at the inlet valve during the retreat stroke of the pump piston on the pump chamber of the connected pump, during which the helium can flow into the pump chamber.

According to the present invention there is provided a non-return valve through which in use gaseous and/or liquid helium may be passed in one direction, the valve comprising a housing defining a chamber in which is located a movable valve closure member made from titanium or an alloy with a titanium content of at least 50%, the valve closure member having an abutment region intended, when the valve is closed, to abut a valve seat around a port, the surface of at least the abutment region of the valve closure member and the surface of the valve seat having a "maximum peak-to-valley height" (as hereinbefore defined) of less than 0.2 μm.

Preferably the valve includes means for guiding the valve closure member within the chamber.

Preferably the "maximum peak-to-valley height" (as hereinbefore defined) is not greater than 0.1 μm.

The use of titanium or a titanium alloy in the construction of the valve closure member allows the moving mass of the valve to be reasonably small. Moreover such materials may be lapped and polished to a smooth surface, and are hard and thus resist scratches. Also, as known, titanium is non-magnetic, so the valve according to the present invention may be operated without adverse interference with superconductive magnets.

Preferably the valve closure member has the form of a disc-shaped lamina and is provided with projecting arms for guiding the valve closure member within the chamber.

Preferably the valve seat is made from stainless, non-magnetic refined steel.

By the expression "maximum peak-to-valley height" of a surface, as used herein, is to be understood the vertical interval between the greatest elevation and the greatest depression on this surface.

The present invention stems from the fact that a relatively high through-flow capacity of a helium pump is made possible by a good sealing of its valves. High demands must in fact be made on the tight seal of a valve of a helium pump because helium has the lowest viscosity of all known media. Thus, for example, the viscosity of gaseous helium at 5°K is approximately

1.3×10^{-5} poise and that of the liquid helium at 4°K is approximately 3.6×10^{-5} poise. The viscosity of liquid helium is lower than that of all other known gaseous substances; for instance, gaseous hydrogen at 300°K has a viscosity of approximately 9×10^{-5} poise. Helium can thus generally penetrate through the smallest gap between the valve closure member and the valve seat so that the through-flow capacity of a pump is thus correspondingly reduced.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 shows a view from above of a valve closure member of one embodiment of a valve according to the present invention and shown in Figure 2;

Figure 2 shows a vertical section through the valve according to that embodiment of the present invention, in the closed position;

Figure 3 shows a vertical section through the valve of Figure 2, in the open position;

Figure 4 shows a cross-section through the same valve taken along the line IV—IV in Figure 3;

Figure 5 shows a vertical section through an alternative embodiment of a valve according to the present invention; and

Figure 6 shows diagrammatically the through-flow capacity of a helium pump with a valve according to the present invention as compared to an equivalent known pump.

In Figure 1, there is shown a valve closure member *2* of a valve for a pump according to the present invention, which closure member *2* basically comprises a disc-shaped lamina 3 provided at its periphery with four projecting arms 5 to 8, arranged at intervals of 90° around the periphery. The outer end region of these arms may expediently slide along the inner surface of a hollow, cylindrical valve housing (not illustrated in Figure 1 but shown in Figure 2), and thus hold the valve closure member *2* centrally within the valve housing. In Figure 1 there is also shown an annular abutment region 9 of the upper surface of the lamina 3 by which region, when the valve is in the closed position, the valve closure member 2 abuts a corresponding valve seat (not shown in Figure 1). The lamina 3 is made from titanium or an alloy with high titanium content. It is manufactured as one piece with the arms 5 to 8.

The valve closure member *2* is provided for a valve which is shown in Figure 2. This valve may for example be the inlet valve of a helium pump (not shown) for conveying liquid or gaseous helium or a corresponding two-phase mixture. The direction of flow of the medium through the valve is from top to bottom and is indicated by arrows 10. The valve also includes a hollow, cylindrical housing 12 provided with a cover 14 and partially defining a chamber 15. The cover 14 is provided with a central bore 16 with a given diameter, through which the helium can be introduced into the valve chamber 15 by way of a supply line 17 (which is shown only in Figure 2). At the lower end of the valve housing 12 the valve chamber 15 is bounded by a base 19, which has a similar form to the cover 14 and is provided with a central bore 20 through which the helium passes into the pump chamber of the helium pump (not shown). On the base 19 there is disposed, within the valve chamber 15 and concentric to the wall of the housing 12, a hollow cylindrical stop member *22*, on which the valve closure member *2* can rest when the valve is fully open. The member *22* includes a ring 23 which is held in position by means of four bars (only three of which, 24 to 26, are shown) which run vertically and are parallel to the inner wall of the housing 12 within the valve chamber 15, the bars extending a given distance from the base 19 towards the cover 14. The outer diameter of the ring 23 is less than the inner diameter of the housing 12 in order to limit the flow resistance of the valve.

According to the embodiment of the valve illustrated in Figure 2, the base 19 and the stop member *22* are formed as a one-piece component which is attached to the valve housing 12 from below, for example it could be screwed on (although the thread is not shown).

Within the stop member *22* there is located a compression spring 28 one end of which bears on the base 19 and the other end of which urges the valve closure member *2* towards the cover 14 of the valve whereby, in the absence of other forces, the bore 16 is closed by the valve closure member *2*. An inwardly directed, annular rim of the cover 14 surrounding the bore 16 serves as a valve seat 30. Since the specific density of the material from which the valve seat is constructed is of secondary importance for a helium pump the cover 14, or at least the valve seat 30, may expediently be manufactured from stainless non-magnetic steel.

In order to achieve an effective seal between the cover 14 and the valve closure member *2* the surface of the valve seat 30 facing the valve closure member *2*, as well as at least the corresponding annular abutment region 9 of the valve closure member *2*, is so smoothly worked that its peak-to-valley height is less than 0.2 μm. Only with such a low degree of surface roughness is a high through-flow capacity

of the helium pump obtained. Expediently, not only the annular abutment region 9 of the valve closure member *2*, but also the entire lamina 3 as shown in Figure 1 has a correspondingly smooth surface.

The valve in the open position is shown in Figures 3 and 4. As the outer diameter of the ring 23 of the stop member *22* is less than the inner diameter of the housing 12 and as the outer diameter of the lamina 3 of the valve closure member *2* is smaller than the inner diameter of the ring 23, the valve closure member *2* only rests on the ring 23 by means of its arms 5 to 8. An annular zone 32 is then left clear between the ring 23 and the lamina 3 which is interrupted only by the arms. Through this zone 32, the helium can flow directly past the lamina 3. The corresponding helium stream is indicated by broken lines 34 marked by crosses. In addition, the helium can also pass through the side of the stop member *22*. In this case the gas flows from an area 35 located between the stop member *22* and the inner wall of the housing 12, then between the bars 24 to 26 of the stop member 22 into the space defined by the stop member *22*, and from there through the bore 20 in the base 19. This helium stream is indicated by broken lines 36 marked by circles. This design of the stop member *22* and the valve closure member *2* ensures that the cross-section of flow through the inlet bore 16 in the cover 14 and through the outlet bore 20 in the base 19 is not reduced when the valve is open, and thus an increase in the flow resistance of the valve is avoided.

In Figure 5 an alternative embodiment of a valve in accordance with the present invention is illustrated in longitudinal section. In contrast to the embodiment illustrated in Figures 2 and 3, this valve is inverted so that when the valve is closed the valve closure member 2 seals off a bore in its base. Owing the weight of the valve closure member *2*, the spring 28 of the first embodiment may be dispensed with in this alternative embodiment. This valve can be provided, for example, in the base of a helium pump housing as an inlet valve leading to the pump chamber.

In the embodiment illustrated in Figures 1 to 4, the valve, which is for a helium pump, has its closure member *2* formed of titanium with a total weight of 0.73 g (0.006 N). The overall diameter of the closure member *2* inclusive of the arms 5 to 8 is approximately 16.8 mm and the diameter of the lamina 3 is approximately 12.8 mm. This lamina 3 has a thickness of approximately 1.5 mm, and the peak-to-valley height of its upper surface is finished to approx. 0.1 μm in several polishing processes, for example by lapping and subsequent polishing. The spring 28 is manufactured from 0.3 mm thick, non-rusting spring steel with 5 coils and an outer diameter of 13 mm, and, if unrestrained, has a length of 25 mm. In the assembled condition, when the valve is closed, the spring 28 is compressed to 17 mm and presses the valve closure member *2* with a force of approximately 0.088N against the valve seat 30, which is made from stainless refined steel. The inner diameter of the housing 12 amounts to approximately 17 mm. The ring 23 has an outer diameter of approximately 14 mm and a wall thickness of approximately 0.4 mm. The bores 16 and 20 each have a diameter of 11 mm. Since a suction effect should be avoided in a helium pump, the helium gas must exert a force of at least 0.082N on the valve closure member of each inlet valve of such a pump to overcome the force (0.088N) of the spring 28 less the force (0.006N) attributable to the weight of the closure member 2.

In the diagram in Figure 6, the through-flow capacity of a double-acting helium piston pump is plotted as a function of the number of strokes (H) per minute (min) of its pump piston. The through-flow capacity is measured in litres (L) of liquid helium per hour (h). The pump piston diameter is approximately 32 mm and the inlet and outlet valve associated with the pump have the measurements described above. With a known embodiment of this pump, for example in accordance with the German Offenlegungsschrift 2,155,624, and using known valves, there is thus obtained a through-flow capacity corresponding to the two curves I and II drawn with broken lines, the lower curve I being obtained when there is a back pressure downstream of the pump of 0.6 bar, and the upper curve II being obtained when there is no back pressure downstream of the pump. By back pressure is meant the pressure which acts against the outlet valves of the pump. This back pressure can be caused, for example, by resistances in the devices connected to the pump. The known valves have the same form as indicated in Figures 1 to 3, but the valve closure member is formed of a hard aluminium/copper/magnesium alloy (in fact that known by the registered Trade Mark "Dural") with a surface roughness of approximately 4 μm and a weight of 0.48 g. If, in accordance with the present invention the valves used with the known pump are provided with valve closure members of titanium with a peak-to-valley height of 0.1 μm and the valve seats are made from stainless refined steel polished to a corresponding peak-to-valley height, higher through-flow capacities are obtained corresponding to the curves III and IV

traced at a back pressure of 0.6 bar, and 0 bar, respectively.

It can be noted from Figure 6 that, with valves of the known type, an increase in the number of strokes substantially above 250 strokes/min effects no further increase in the volumetric throughput of the pump. This must be ascribed mainly to mechanical defects in the surface of the valve laminae which causes a reduction in the sealing capacity of the valves. On the other hand, with the valves in accordance with the present invention, a higher volumetric throughput, in comparison to the known valves is achieved even at 250 strokes/min. This can be further increased by the fact that a higher number of strokes/min of the pump can be attained without there being any serious risk of damage to the valve laminae. This fact can be attributed in particular to the hardness of the material of the valve laminae, as a result of which damage to the sealing surfaces of the valve can be largely avoided.

In the embodiments illustrated in Figures 1 to 5, the valve closure member, which is disposed in the valve housing, is formed by only one valve disc. Other forms of valve closure member may also be used, however, for example with a stem-like shaft, if the conditions for a through-flow of liquid and gaseous helium are fulfilled. These conditions must be fulfilled in particular for the inlet valves. Since the formation of under pressure does not occur with the liquid helium at the outlet valves of the pump, other valve types may be provided for this purpose.

WHAT WE CLAIM IS:—

1. A non-return valve through which in use gaseous and/or liquid helium may be passed in one direction, the valve comprising a housing defining a chamber in which is located a movable valve closure member made from titanium or an alloy with a titanium content of at least 50%, the valve closure member having an abutment region intended, when the valve is closed, to abut a valve seat around a port, the surface of at least the abutment region of the valve closure member and the surface of the valve seat having a "maximum peak-to-valley height" (as hereinbefore defined) of less than 0.2 μm.

2. A valve according to Claim 1, which includes means for guiding the valve closure member within the chamber.

3. A valve according to Claim 1 or 2, wherein the "maximum peak-to-valley height" (as hereinbefore defined) is not greater than 0.1 μm.

4. A valve according to any preceding claim, wherein the valve closure member has the form of a disc-shaped lamina and is provided with projecting arms for guiding the valve closure member within the chamber.

5. A valve according to any preceding claim, wherein the valve seat is made from stainless, non-magnetic refined steel.

6. A valve substantially as hereinbefore described with reference to, and as illustrated in, Figures 2 to 4 or Figure 5 of the accompanying drawings.

7. A pump for conveying gaseous and/or liquid helium, provided with a valve according to any preceding claim.

HASELTINE, LAKE & CO.,
Chartered Patent Agents,
28 Southampton Buildings,
Chancery Lane,
London WC2A 1AT
and
Temple Gate House,
Temple Gate,
Bristol BS1 6PT
and
9 Park Square,
Leeds LS1 2LH.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

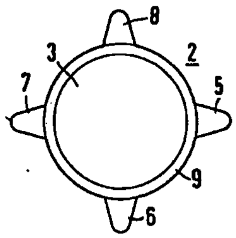

Fig. 1

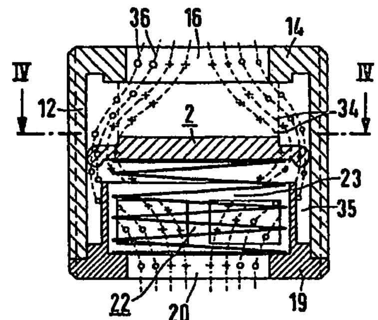

Fig. 3

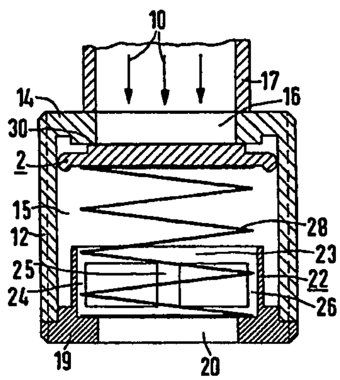

Fig. 2

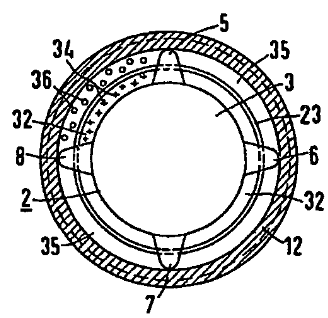

Fig. 4

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1541792 COMPLETE SPECIFICATION

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Sheet 2

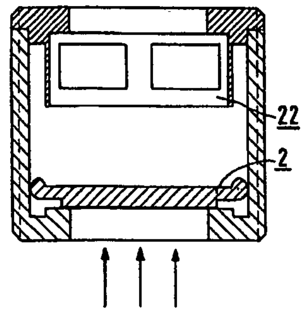

Fig. 5

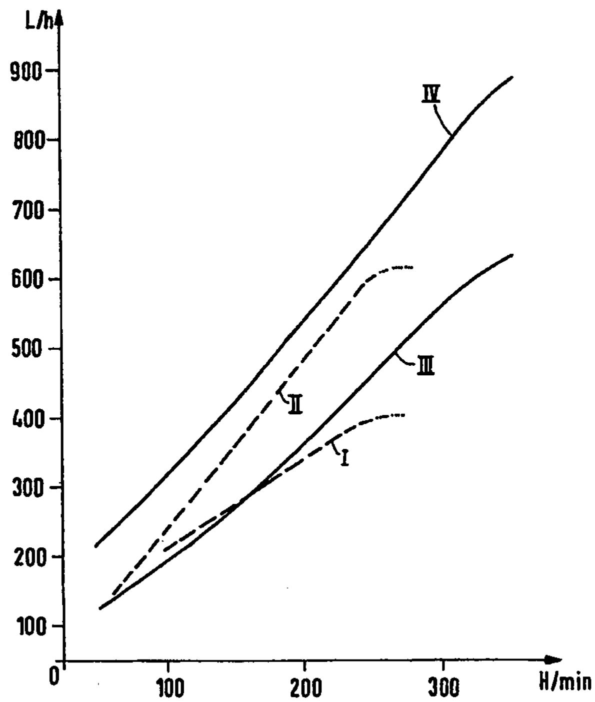

Fig. 6